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A COMPARISON OF POSSIBLE METHODS FOR MARINE FOULING ASSESSMENT --ETC(U)

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**DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION**  
**MATERIALS RESEARCH LABORATORIES**

MELBOURNE, VICTORIA

**REPORT**

MRL-R-808

A COMPARISON OF POSSIBLE METHODS FOR MARINE FOULING  
ASSESSMENT DURING RAFT TRIALS

John A. Lewis

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**ABSTRACT**

Fouling settlement data from HMAS STIRLING (Western Australia), the North Barnard Islands (North Queensland) and Williamstown (Victoria) were used to evaluate the suitability of different methods for settlement. Density, cover, frequency and biomass measures were used to assess the abundance of settlement on panels immersed during raft trials. Frequency proved to be the most suitable measure of individual species abundance for comparisons both within and between study sites. Density measures could not be applied to all species, whilst the panel cover of individual species was generally too low for effective comparison of abundance. Panel cover and biomass were better indices of total fouling abundance than either density or frequency. A draft method for assessment of fouling settlement on test panels based on these findings, and suitable for use in conjunction with Australian Standard 1580 test-method 481.5, is appended.

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## 16. ABSTRACT (if this is security classified, the announcement of this report will be similarly classified):

Fouling settlement data from HMAS STIRLING (Western Australia), the North Barnard Islands (North Queensland) and Williamstown (Victoria) were used to evaluate the suitability of different methods for settlement. Density, cover, frequency and biomass measures were used to assess the abundance of settlement on panels immersed during raft trials. Frequency proved to be the most suitable measure of individual species abundance for comparisons both within and between study sites. Density measures could not be applied to all species, whilst the panel cover of individual species was generally too low for effective comparison of abundance. Panel cover and biomass were better indices of total fouling abundance than either density or frequency. A draft method for assessment of fouling settlement on test panels based on these findings, and suitable for use in conjunction with Australian Standard 1580 test-method 481.5, is appended.

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## A COMPARISON OF POSSIBLE METHODS FOR MARINE FOULING

### ASSESSMENT DURING RAFT TRIALS

#### 1. INTRODUCTION

The resistance of marine underwater paint systems to fouling is experimentally assessed by inspecting test panels below a raft in areas where fouling organisms are known to settle. Details and procedures for tests are prescribed in Australian Standard 1580, test method 481.5 [1]. The performance of paint systems is monitored at four-week intervals when panels are inspected for the presence of fouling. Control panels are immersed for successive four-week periods to ensure that potential fouling organisms are present around the raft. Detailed analyses of fouling settlement at test sites involve counts of the number of individuals of each of the major species which settle on the control panels.

During MRL studies on marine fouling in different geographic regions of Australia [2-4], inadequacies were found in the use of settlement counts to assess fouling abundance. These inadequacies were:

- (a) individuals of some species, for example stoloniferous hydroids and tufted filamentous algae, cannot be readily defined or counted.
- (b) variation in the size of individuals between species does not permit valid comparison of settlement counts to determine the relative importance of different species within the fouling community.
- (c) the size of colonial organisms with spreading, almost two-dimensional, growth forms is not taken into account when a colony is counted as one individual, and
- (d) the severity of fouling at different localities cannot be compared unless the same species occur at each locality.

In this study, alternative methods of assessment are compared to determine the best method for assessment of fouling abundance on test panels during raft trials. The four methods compared, although primarily applied to gain quantitative data in terrestrial plant communities [5,6], have each been previously used in fouling studies [7-14]. This secondary application is possible because of the similarity in structure of terrestrial plant and marine epibenthic communities. The assessment methods compared are:

- (a) density, or the number of individuals on a specified area of panel surface [7,8].
- (b) cover, or the percentage of surface covered by each species [9,10].
- (c) frequency, or the probability of a species occurring in a specified area [11,12], and
- (d) biomass [13,14].

## 2. METHODS

### *2.1 Test Panels*

Assessment methods were compared on a series of panels immersed to obtain settlement data for the paint-test raft at HMAS STIRLING on Cockburn Sound, Western Australia [4]. Eleven panels (30 cm x 15 cm x 3 mm) of black unplasticised polyvinyl chloride were suspended vertically below the raft at an approximate depth of 1 m for successive periods of one month. One panel from Queensland (North Barnard Island; immersion period 29/5/79 - 28/8/79) and one from Victoria (Williamstown Naval Dockyard; immersion period 20/4/79 - 22/5/79) were also assessed by the same methods to evaluate between-site comparisons.

### *2.2 Assessment Methods*

- (a) *Density.* All organisms within an area 10 cm x 10 cm in the centre of each panel surface were identified and counted.
- (b) *Cover.* The number of intercepts of each species with intersects of a 0.5 cm grid were counted over the central 24 cm x 13 cm area of the panel and converted to percentage of the total grid points.
- (c) *Frequency.* The presence or absence of each species within one hundred 5 mm x 5 mm squares scribed on a perspex overlay was determined. The number of squares in which a species was present gives the percentage probability of that species occurring in the assessment area.

- (d) *Biomass*. Panels were oven-dried (40°C, 24 h) and the fouling scraped from a 10 cm x 10 cm area in the centre of each panel side and weighed. No attempt was made to determine the biomass of individual species.

With the exception of regression calculations, data from only one side of the panels are considered for the purpose of this report.

### 3. RESULTS

#### *3.1 Variation Within Species*

Variation in frequency and density measures for the barnacles *Balanus* spp. (Figure 1) and the tubeworm *Janua pagenstecheri* (Figure 2), the most numerous hard-shelled foulers at the HMAS STIRLING raft site (Table 1), suggests a linear relationship between these two measures. Regressions of frequency on density show significant correlation ( $p < 0.01$ , Figure 3), although the slope of the regression line differs for each species (Figure 4).

Cover values for *Balanus* spp. and *Janua pagenstecheri* are all low with the exception of *Balanus* on panel 10 (Figure 1). This panel remained immersed for twice the period of other panels in the series. Cover assessment often failed to detect a species present in low abundance (eg *Pileolaria militaris*, Figure 5).

Density methods could not be used to assess the abundance of filamentous algae (*Enteromorpha*/Ectocarpaceae spp.), tube-dwelling amphipods or the hydroid *Obelia nodosa*. The algae and amphipods occurred in dense populations within which individuals could not be readily distinguished whereas the hydroid has a stoloniferous habit with similar problems in individual definition. Both cover and frequency were suitable measures of abundance for these taxa (Figures 6,7). Frequency methods produced higher abundance values than cover for most panels, particularly those with low cover values ( $< 5\%$ ). Variation between panels was therefore more apparent using frequency than cover methods when species abundance was low, although the converse applied when abundance was high. Regression of frequency on cover for the tube-dwelling amphipods shows significant linear correlation ( $p < 0.01$ , Figure 7). Data for other species were not suitable for similar analyses.

#### *3.2 Variation Between Species*

Plots of density and frequency values for hard-shelled invertebrates allow visual comparison of species abundance (Figure 8). Cover values for the same species are generally too low for similar inter-specific comparisons. The abundance of *Enteromorpha*/Ectocarpaceae spp. and of the tube-dwelling amphipods can be satisfactorily compared by either cover or frequency measures, but frequency is a more sensitive indicator of *Balanus* presence when plotted on the same scale (Figure 9).



T A B L E 1

AVERAGE ABUNDANCE OF THE TEN MOST ABUNDANT SPECIES ASSESSED BY EACH

METHOD ON THE FRONT OF ONE-MONTH PANELS FROM HMAS STIRLING

(\*unable to be assessed by this method)

Species	Density Individ./dm <sup>2</sup>	Cover %	Frequency %
<i>Enteromorpha</i> /Ectocarpaceae spp. (green/brown algae)	*	58	65
Tube-dwelling amphipods	*	23	31
<i>Balanus trigonus</i> Darwin/ <i>B. variegatus</i> Darwin (barnacles)	163	2	23
<i>Janua pagenstecheri</i> (Quatrefages) (tubeworm)	108	<1	23
<i>Mytilus edulis</i> Linnaeus (bivalve mollusc)	35		5
<i>Bugula stolonifera</i> Ryland (erect bryozoan)	13	<1	2
<i>Pileolaria militaris</i> Claparede (tubeworm)	10		2
<i>Ulva lactuca</i> Linnaeus (green alga)	7		
<i>Filograna implexa</i> Berkeley (tubeworm)	6	<1	3
<i>Bugula neritina</i> (Linnaeus) (erect bryozoan)	6	<1	3
<i>Botryllus schlosseri</i> (Pallas) (compound ascidian)	4		
<i>Serpula vermicularis</i> Linnaeus (tubeworm)	3		
<i>Obelia nodosa</i> Bale (hydroid)	*	<1	4
Unid. compound ascidian sp.		<1	
Corellidae sp. (solitary ascidian)		<1	

A comparison of the ten most abundant species assessed by each method during the study period (Table 1) shows frequency to be the most useful measure. Density could not be used for all species and cover values were mostly low. Frequency was suitable for all species and percentages were evenly spread over the scale.

### 3.3 Variation in Total Fouling Abundance

Of the four assessment methods, all but frequency illustrate sizeable variation in total fouling abundance through the study period (Figure 10). Frequencies of, or approaching, 100% were recorded for all but two panels and this method therefore contains little information on total fouling abundance.

### 3.4 Variation Between Sites

Density (Table 2) and frequency (Table 3) values for the major groups of fouling organisms at different study sites provide suitable comparative data whereas cover values (Table 4) are mostly too low for differences to be evident. Some algal and hydroid species could not be assessed by density methods and density values therefore do not represent all fouling species on the panels. Cover and biomass methods provide the most useful data for comparison of total fouling (Table 5).

T A B L E 2  
DENSITY (INDIV./dm<sup>2</sup>) OF MAJOR FOULING GROUPS AT DIFFERENT STUDY SITES  
(\*present, but unable to be assessed by this method)

Group	WA (Panel 11)	Vic	Qld
Algae	*	0	*
Hydroids	*	0	*
Tubeworms	28	42	1
Sponges	1	0	3
Molluscs	0	0	9
Enc. Bryozoans	9	0	5
Erect Bryozoans	5	5	0
Comp. Ascidians	4	24	4
Sol. Ascidians	0	15	0
Barnacles	1209	469	3

TABLE 3  
FREQUENCY (%) OF MAJOR FOULING GROUPS AT DIFFERENT STUDY SITES

Group	WA	Vic	Qld
Algae	0	0	17
Hydroids	26	0	97
Tubeworms	10	17	1
Sponges	0	0	1
Molluscs	0	0	1
Enc. Bryozoans	4	0	13
Erect Bryozoans	3	7	0
Comp. Ascidians	2	17	4
Sol. Ascidians	0	1	0
Barnacles	100	76	3

TABLE 4  
PANEL COVER (%) OF MAJOR FOULING GROUPS AT DIFFERENT STUDY SITES

Group	WA	Vic	Qld
Algae	0	0	)90
Hydroids	0	0	)
Tubeworms	0	<1	0
Sponges	0	0	<1
Molluscs	0	0	<1
Enc. Bryozoans	<1	0	4
Erect Bryozoans	<1	2	0
Comp. Ascidians	<1	<1	1
Sol. Ascidians	0	<1	<1
Barnacles	11	2	1

T A B L E 5  
VARIATIONS IN TOTAL FOULING ON PANELS FROM DIFFERENT STUDY SITES  
(\*excluding algae and/or hydroids)

	WA	Vic	Qld
Density (Indiv/dm <sup>2</sup> )	1257*	555	25*
Cover (%)	12	4	97
Frequency (%)	100	88	100
Biomass (g/dm <sup>2</sup> )	0.53	0.06	0.35

#### 4. DISCUSSION

##### 4.1 Appraisal of Assessment Methods

###### 4.1.1 Density

Density is an absolute measure of abundance and is the most accurate means for comparing the abundance of solitary organisms. However, density methods cannot be satisfactorily applied to species whose growth form prevents the simple definition of individuals. Similar problems arise in the use of density to assess many grasses and sedges encountered in terrestrial plant ecology [6]. Furthermore density is not a meaningful index of abundance for spreading colonial organisms such as compound ascidians, sponges and encrusting bryozoa.

Additional problems in the use of density measures arise in comparisons between different species. For example, fewer individuals of one species would be able to settle within a defined area than individuals of a second species if the former species had larger individuals than the latter. In a fouling community, a species with large, sparsely-distributed individuals may be more important in terms of substrate cover and biomass than a species with small, more-numerous individuals; but density measures do not assess this relative importance.

###### 4.1.2 Cover

Cover measurement overcomes most of the difficulties inherent in density methods. All species are assessed on a common scale, the extent of spreading colonial organisms is easily measured and, in most cases, organisms such as filamentous algae and hydroids, which cannot be readily assessed by density counts, can be assessed by cover estimates. Problems can occur, however, when

several species of hydroid or alga coexist in a tangled mat.

The principal disadvantage of cover assessment in the present study was that densities of most organisms were low and/or individuals small (see Section 3). The percentage cover for individual species therefore approached zero and little comparative data were obtained. Cover assessment methods used for this report were also time-consuming. The number of points in the grid (approximately 1200) was, however, higher than perhaps necessary. Sutherland and Karlson [9] found that 75 random points measured cover values to within  $\pm 5\%$  of planimeter estimates, adequate for assessment of the more common species. Bohnsack [15] presents a table of standard errors, evaluated by the Gauss equation [16], associated with a given number of points for a range of cover values. A high number of points is justified only for species with low ( $<10\%$ ) cover values. The majority of species on panels immersed for only one month cover less than 10% of panel surface (see Table 1) so little could have been gained by a reduction in the number of points. When panel cover by individual species is high, as for example on panels immersed for periods longer than one month, or if only the total fouling cover is required, an array of 100 random points would generally be sufficient for cover estimation.

#### 4.1.3 Frequency

Frequency incorporates elements of both density and cover in a single parameter. All species are assessed on a common scale and less time is required to assess frequency than either density or cover. The error in frequency estimates is negligible compared with estimates of density or cover [6].

Frequency is not an absolute measurement and results depend on the size of the quadrats used in assessment. However, if quadrat size is kept constant, results are directly comparable both within and between studies and study sites.

The relationship between frequency and density varies between species (Figure 4). Frequency measures the probability of occurrence of a species within a defined area and therefore depends not only on quadrat size but also on individual size. For example, on one-month panels in this study individuals of *Bugula neritina* were larger than individuals of *Mytilus edulis* and fewer individuals of *B. neritina* than *M. edulis* would need to be present to result in the same frequency (Figure 4). The size of an individual on a test panel depends on its time of settlement, growth rate and potential mature size. The frequency/density relationship for any species will therefore vary on panels immersed for different periods and possibly between study sites. The spatial distribution of a species will also affect its frequency. Species which do not settle randomly across a panel surface but congregate in localised patches will have a low frequency despite a possible high density. Overall the complexity of the relationship prevents the conversion of density to frequency, or vice versa, from measurements of a single parameter. Similar problems would arise in any attempts to convert frequency measures to cover.

Frequency was not a useful index of total fouling abundance in the present study (see Section 3.3). Frequency values could be reduced to more workable figures by a reduction in quadrat size; the extreme of which is the point-intercept method as used to measure cover. The direct assessment of cover, an absolute measure of quantity, is preferable to a reduction in quadrat size when such quadrats would only be used to assess total fouling abundance.

#### *4.1.4 Biomass*

Biomass was too cumbersome for the assessment of individual species abundance, but useful as a measure of total fouling abundance both within (Figure 10) and between studies and study sites (see Table 5). Although only dry weight per unit area was assessed in this study, wet weight can similarly be measured to take greater account of fouling organisms without hard shells. The scraping and weighing of fouling from a defined area of panel surface is a better method of biomass assessment than comparison of panel weights before and after immersion, particularly when panels support a low biomass (<10 g/panel). Apart from the greater accuracy, the former method overcomes the non-uniform settlement of organisms near panel edges and allows comparison of biomass between panel sides.

#### *4.2 Applicability of Assessment Methods to Panel Studies*

The most appropriate method for assessing fouling abundance in a particular study depends on the aims of that study. If a study is to focus on the settlement of a single solitary species, such as a barnacle or tubeworm, then density is the best quantitative measure. Alternatively, if the study is on changes in fouling composition with increased immersion time, then cover is a better method. In the present work, the aim was to assess the abundance of different fouling species on panels immersed for short periods (one month) and generate data which could be used as the basis for comparisons within and between studies and study sites. Density was unsuitable as it could not be measured for all species and cover values were too low to permit effective comparisons. Frequency overcame difficulties in both these methods and enabled all species to be compared on a common scale. Frequency was also suitable to compare abundance of the major fouling groups between study sites. However, a standard method, particularly with regard to quadrat size, would have to be used to ensure that comparisons are valid. A draft method suitable for panel assessment is outlined in the appendix. Statistical tests can be applied to frequency data but an arcsin, or angular, transformation may be needed to normalise the data [17]. Alternatively, non-parametric statistical methods can be applied.

Frequency and density were both found to be unsuitable for assessment of total fouling abundance. Cover and biomass however both appear suitable for this purpose and measure attributes of the community important to the performance of underwater material; viz. the proportion of a surface likely to be covered by fouling growth and the added weight.

## 5. CONCLUSION

Of the methods used to assess fouling abundance on test panels, frequency was found to be more suitable than density, panel cover or biomass for comparisons of individual species abundance both within and between study sites on panels immersed for periods of approximately one month. Panel cover and biomass were better than either frequency or density as indices of total fouling abundance.

## 6 ACKNOWLEDGEMENTS

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## APPENDIX

### Draft Method for Assessment of Test Panels

The following method is proposed for the assessment of control panels and test panels during raft trials. Details on control and test panels and procedures are prescribed in Australian Standard 1580 [1].

#### *A-1 Organism Frequency*

A 'Perspex' or similar transparent plastics sheet, of the same dimensions as the test panel, with one hundred 5 mm x 5 mm squares scribed in a regular array within the central 12 cm x 20 cm area of the sheet surface, is placed on the test panel. The presence or absence of each major fouling group (Table A-1; refer to MRL Report 644 for illustrations [2]) or species, if these are well known at the study site, within each square is determined and totals expressed as percentage frequency.

#### *A-2 Total Fouling Cover*

The presence or absence of fouling below 100 random points scribed on a 'Perspex' overlay is determined. The total number of presence scores gives percentage cover.

#### *A-3 Fouling Biomass*

Panels are oven-dried (40°C, until panels remain at a constant weight) and the fouling scraped from an area 10 cm x 10 cm in the centre of the panel surface and weighed.

Procedures A-1 to A-3 are applied to each panel surface. An example of results is given in Table A-1.

#### *References*

1. Australian Standard 1580, test-method 481.5.
2. Russ, G.R. and Wake L.V. (1975). A manual of the principal Australian marine fouling organisms. MRL Report 644.

### T A B L E    A-1

### EXAMPLE OF FOULING ASSESSMENT RESULTS

SITE: HMAS STIRLING PANEL NO: D11  
IMMERSION PERIOD: 28/3/80 - 28/4/80  
PANEL DETAILS: Black, sandblasted polyvinyl chloride

**A. Organism Frequency (%)**

Fouling Group	Panel Side	
	Front	Back
Algae: Green	33	0
Brown	100	0
Red	0	0
Sponges	0	0
Hydroids	0	26
Tubeworms	1	10
Molluscs	0	0
Bryozoans: Encrusting	4	4
Erect	1	3
Ascidians: Compound	3	2
Solitary	0	0
Barnacles	100	100
Other	0	0

B. Total Fouling Cover (%)	100	12
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C. Total Fouling Biomass (g/dm <sup>2</sup> )	0.063	0.053
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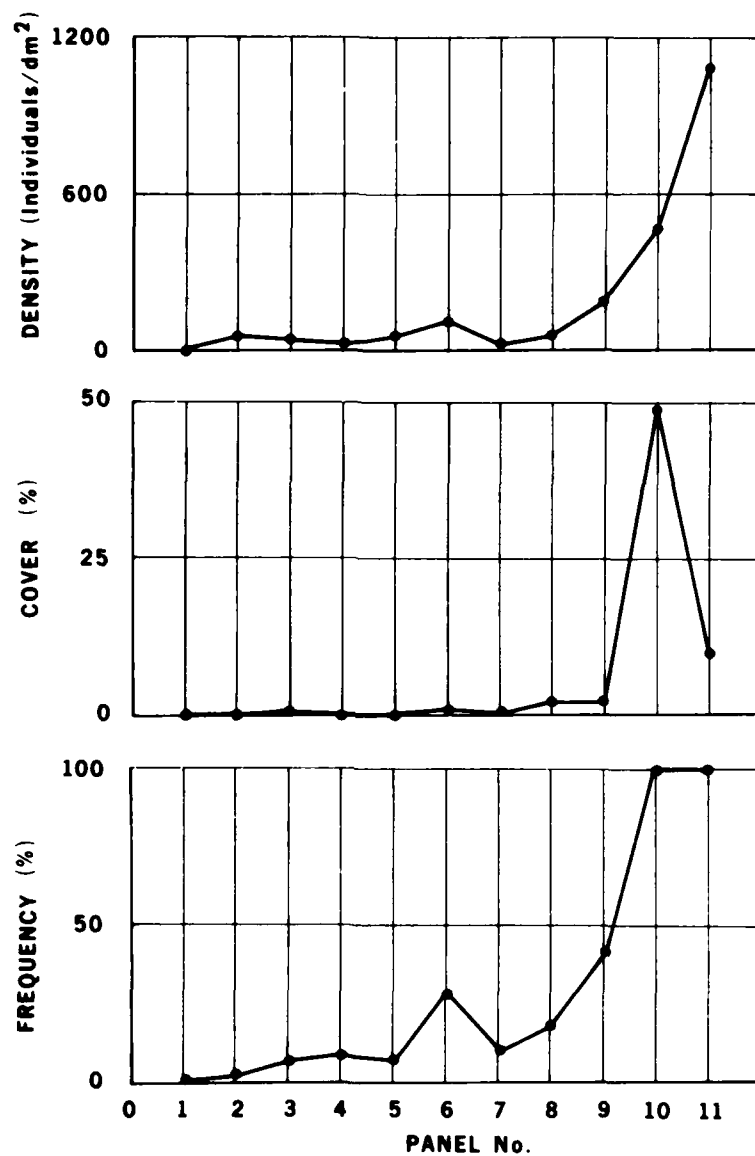


FIG. 1 - Variation in abundance of *Balanus* spp. as assessed by different methods on panels from HMAS STIRLING.

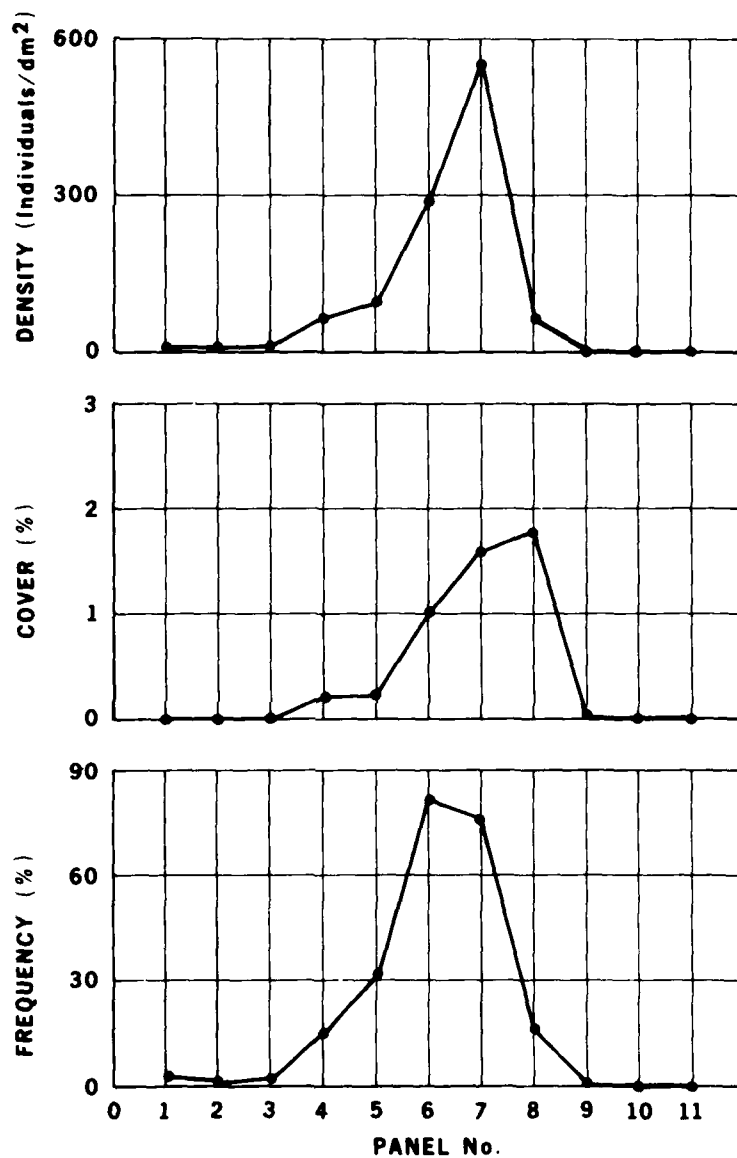


FIG. 2 - Variation in abundance of *Janua pagenstecheri*.

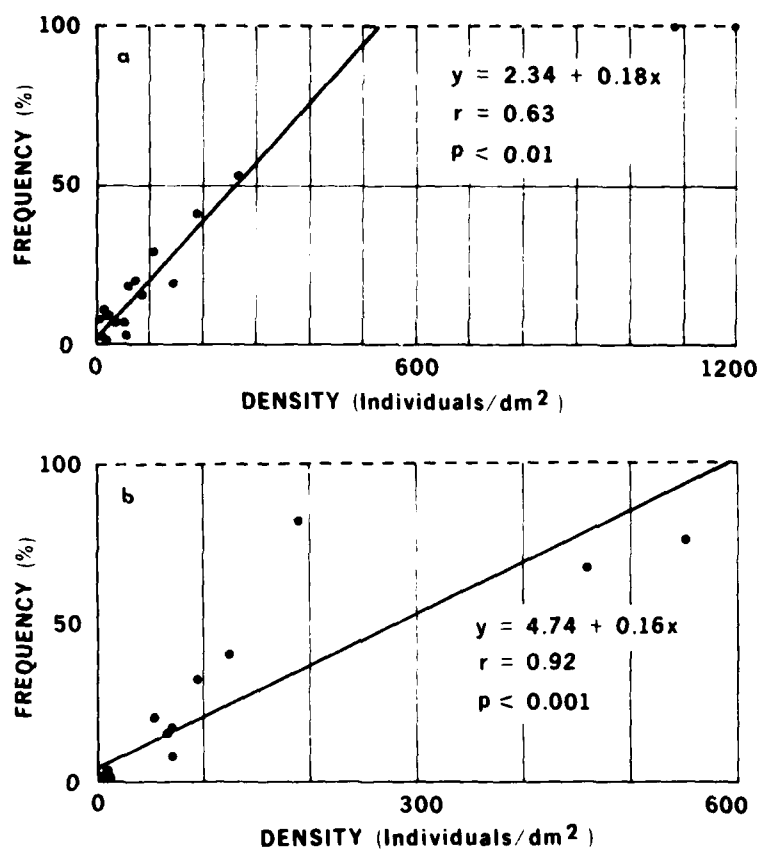


FIG. 3 - Scattergram and linear regression of frequency on density for  
a. *Balanus* spp. and b. *Janua pagenstecheri*.

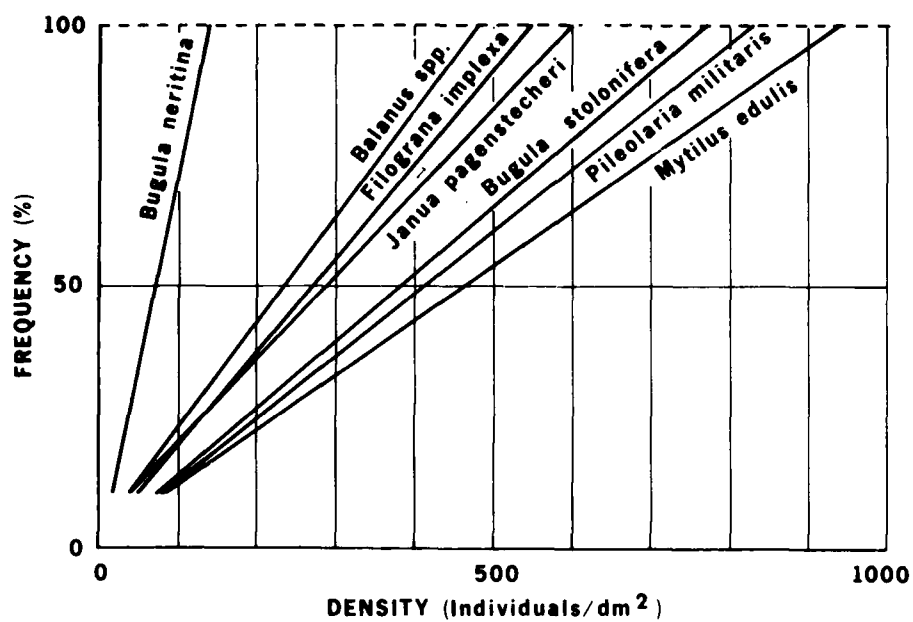


FIG. 4 - Linear regression of frequency on density for the most numerous organisms on study panels.

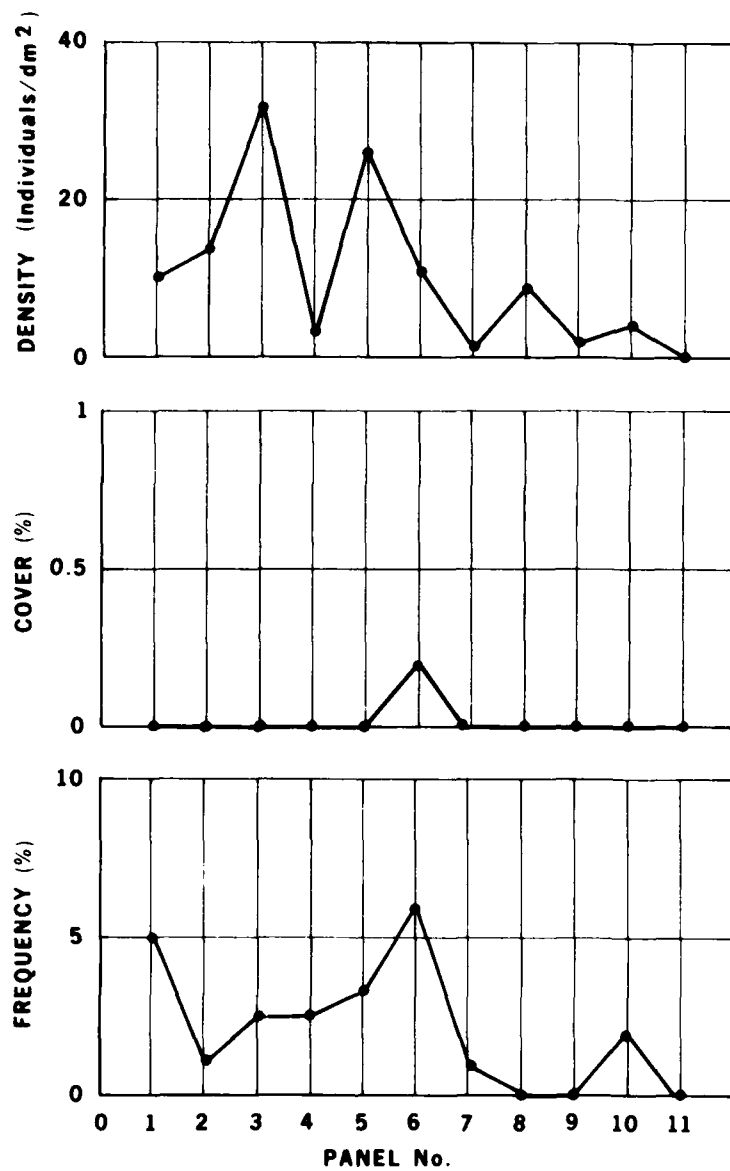


FIG. 5 - Variation in abundance of *Pileolaria militaris*.

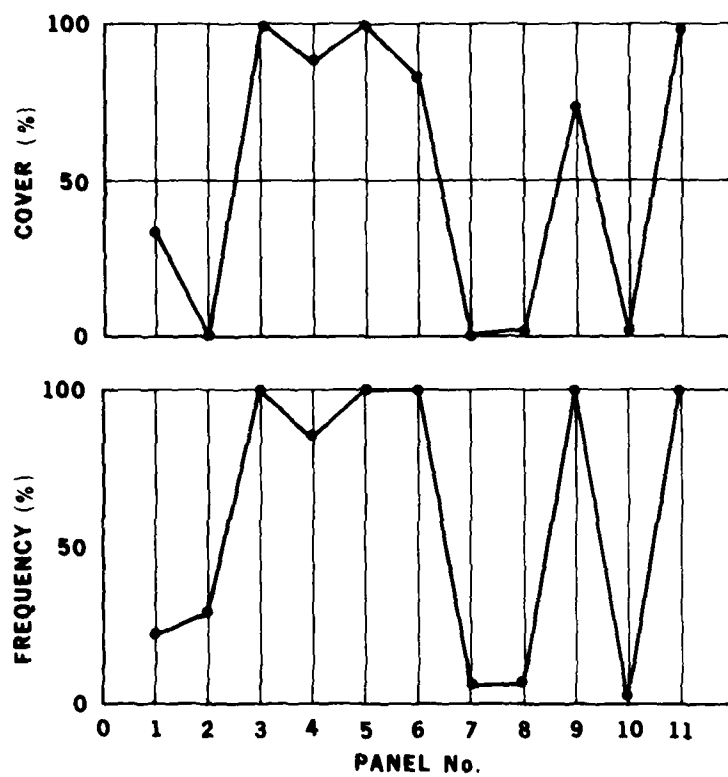


FIG. 6 - Variation in abundance of *Enteromorpha*/Ectocarpaceae spp.



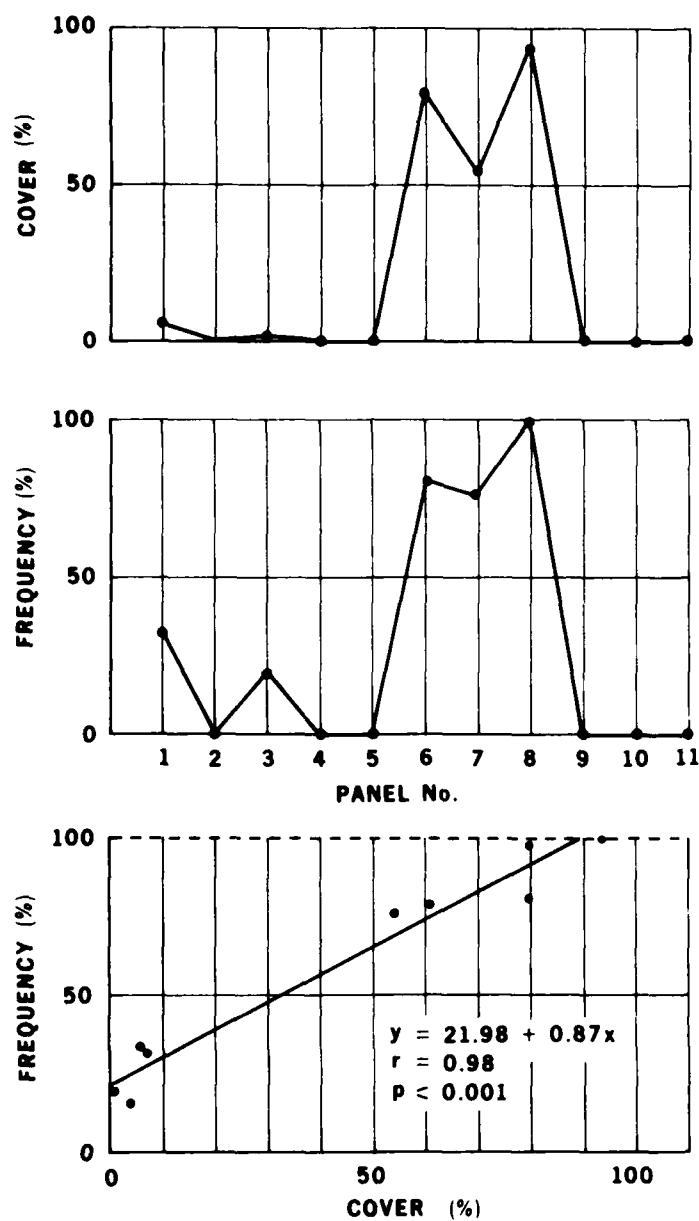


FIG. 7 - Variation in the abundance of tube-dwelling amphipods and scattergram and linear regression of frequency on cover.

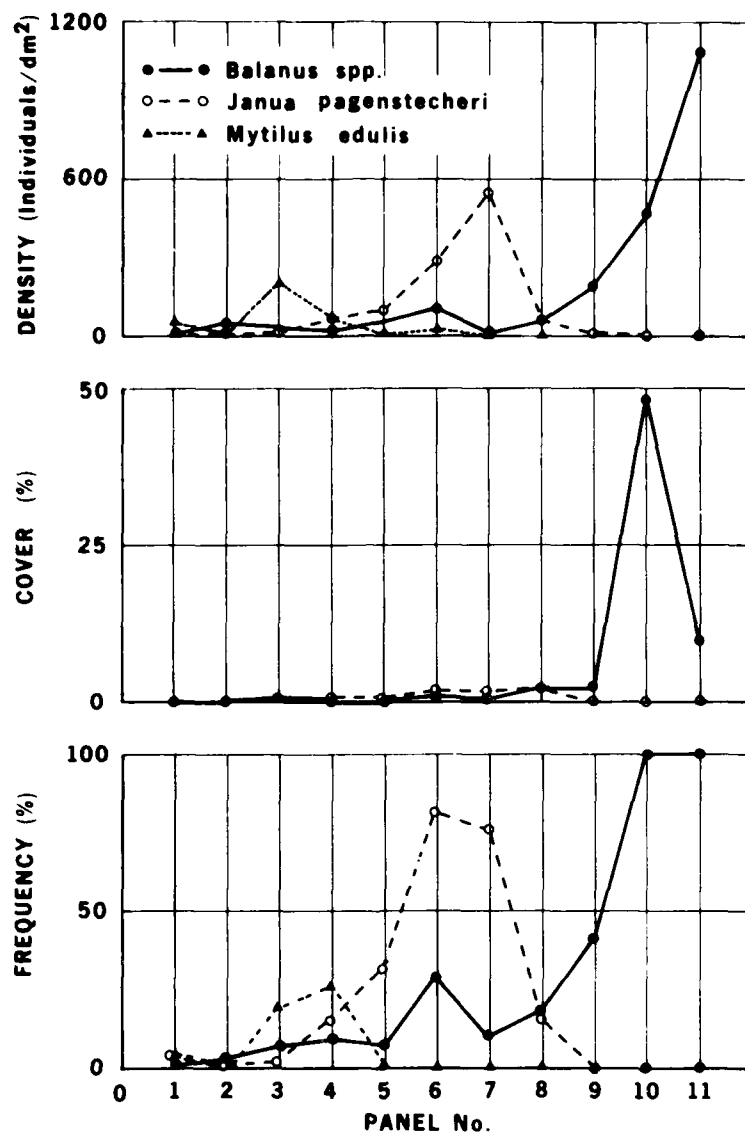


FIG. 8 - Comparison of abundance of the most numerous fouling organisms.

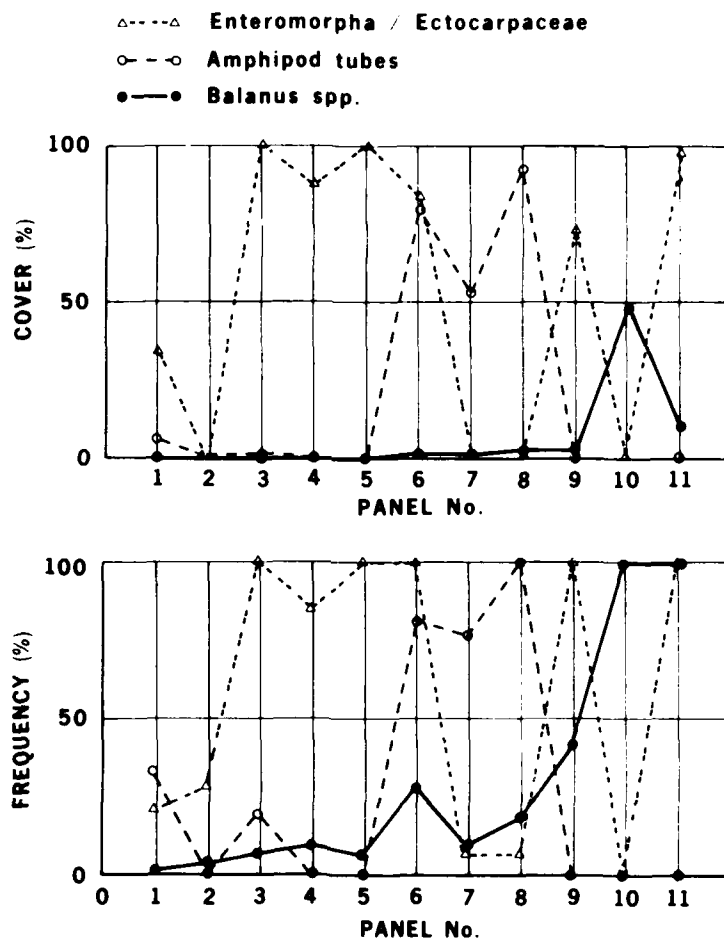


FIG. 9 - Comparison of organisms with the highest panel cover and frequency.

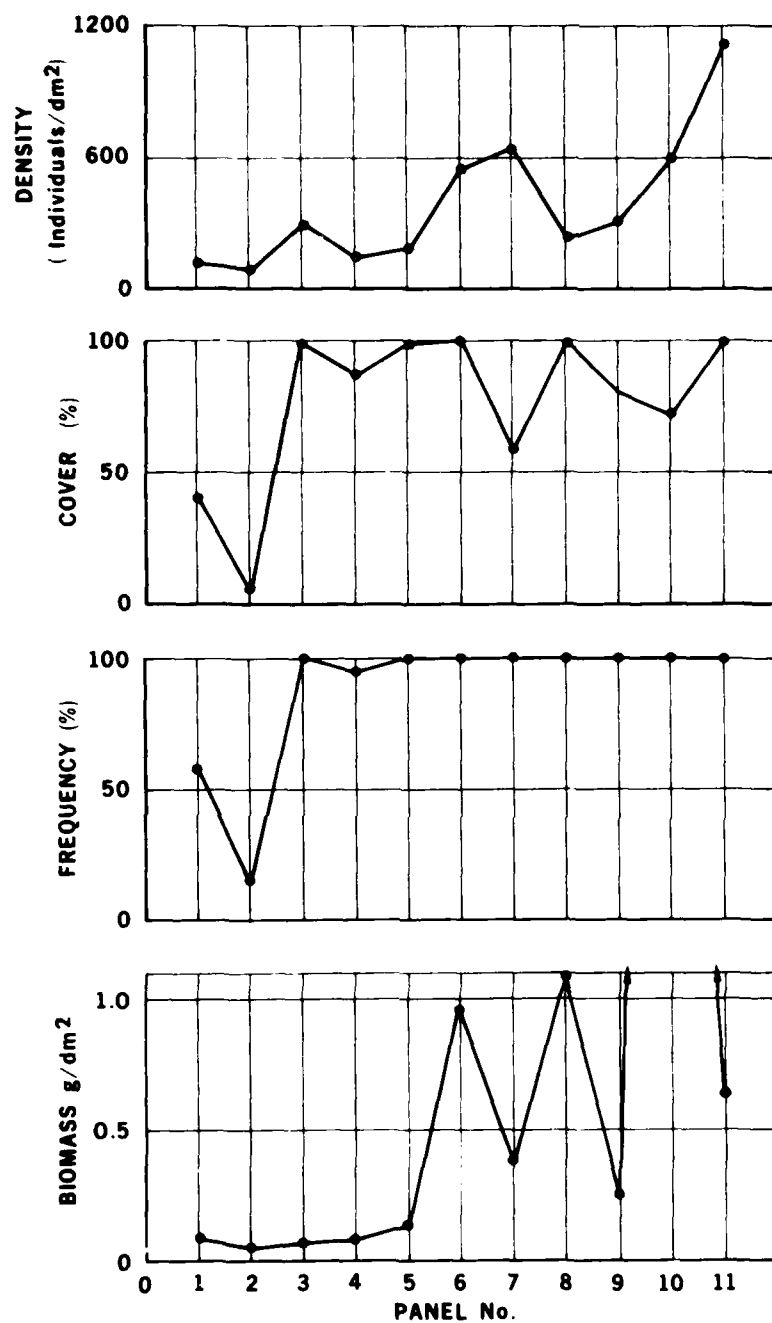


FIG. 10 - Variation in abundance of total fouling.

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